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The Host Affinities of *Isospora bigemina*-Type Coccidia

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Dogs, cats and certain other carnivores are the hosts of a coccidium of the family Eimeriidae known as *Isospora bigemina* (Stiles, 1892) (Fig. 1). This *Isospora* has three outstanding and peculiar characteristics: (1) Its endogenous development takes place in the *lamina propria* or cores of the villi of the small intestine of its host in chronic infections, but in acute infections it may colonize the epithelial cells of the entire small intestine: (*vide* Wenyon, 1926, and Wenyon and Sheather, 1925); (2) Its oocysts sporulate completely *in situ* when occurring subepithelially and are passed in the fully developed condition, but in scanty numbers; (3) The oocyst wall, which contains the two spores, is thin, sometimes so thin it seems to be absent altogether, and is stretched, or even slightly constricted between the spores, so that the term "accordion-like" has come to be applied to the "bigeminal" figure so created; (4) The spores, with comparatively thick walls, are often found singly and free in the feces, usually along with the bigeminal oocysts. Finck (1854) first saw this species and described the sporulated oocysts (*corpuscules géminés*) as he saw them inside the villi of the cat's intestine, though he failed to interpret them as microorganisms. Stiles (1891, 1892), an American working in a laboratory in France, described the species on the basis of the bigeminal nature of its oocysts and their position in the villi of the dog's intestine.

A similar parasite was noted by Kjellberg of Stockholm inside the intestinal villi of a human being who came to autopsy. His observation was reported by Virchow (1860), the renowned German pathologist. This is the only instance of the observation of this parasite in the tissues of the wall of the human intestine, but the bigeminal oocysts and spores have been passed by individuals who probably contracted their infections in countries adjacent to the Mediterranean Sea, Liberia, Argentina, or the United States. The form that occurs in man was named *Coccidium bigeminum* var. *hominis* by Railliet and Lucet (1891), then Wenyon (1923) placed it in the genus *Isospora*, so that the correct name becomes *Isospora hominis* (Railliet and Lucet, 1891) Wenyon, 1923. I have found

literature reports of only 50 cases of infection with this coccidium in man, though the name has sometimes been misapplied to *Isospora belli,* another parasite of man of which I have found 566 cases reported in the literature.

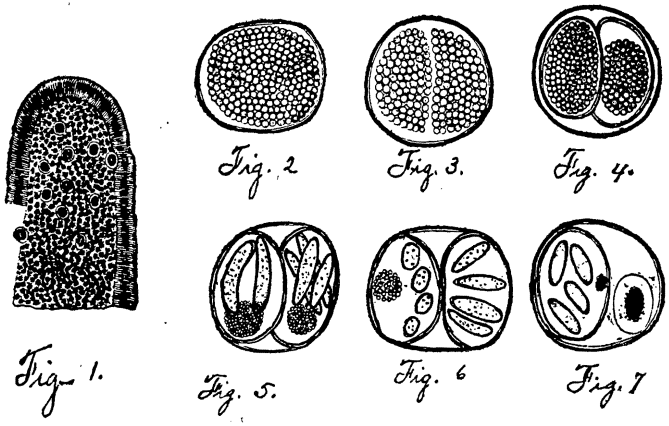

Fig. 1 Reproduction of Stiles' (1892) original figures of Isospora bigemina (retouched).

1. Villus of a dog's intestine showing oocysts in the *lamina propria.* 2. Undeveloped oocyst. 3. Sporoblasts in process of developing. 4. Bigeminal oocyst with immature spores. 5, 6. Bigeminal oocyst with mature spores, each with sporozoites and intra-residual body. 7. Developed oocyst with one degenerated spore.

On account of the comparative rarity of *I. hominis,* many workers believe that human infections are of carnivore origin. Intestinal coccidia tend to exhibit a high degree of host-specificity, but it is possible that *I. bigemina* is a notable exception that spans two host orders—Carnivora and Primates. Other workers are evidently inclined to regard *I. hominis* as a strictly human species, but one that closely resembles *I. bigemina* of carnivores.

It is well-known that *histolytica*-type *Entamoebae* occur naturally in man, monkeys, rats, pigs, certain birds and frogs. While compiling a list of the known species of the genus *Isospora,* I was surprised to learn that counterparts of *Isospora bigemina* also occur naturally in certain lower animals. The "guaicuica" or South America opossum (*Lutreolina crassicaudata*), a marsupial, harbors *Isospora lutreolinae,* described in Brazil by Carini (1939). The fully developed oocysts and individual spores are passed with the feces. The oocysts measure 20-22μ x 17.0-19.0μ. The spores measure 12.0-12.0μ x 9.0-10.μ. The cores of the villi, as observed in scrapings and stained sections, are charged with the developed bigeminal oocysts. *I. boughtoni* Volk (1938) also has oocysts of the *I. bigemina* type. He observed them in the content of the upper

small intestine of the opossum *Didelphys virginiana,* where they developed both in the epithelium and subepithelium.

Carini (1943) reported that the "suindara" or common barn owl in Brazil (*Strix flammea perlata*) harbors *Isospora buteonis* Henry (1932), which produces oocysts of the *I. bigemina*-type measuring 16.0-20.0μ x 15.0μ. Furthermore, stained section of the intestine reveal numerous completely developed oocysts in the cores of the villi, below the epithelial layer. Henry originally described the oocysts from hawks and owls, but apparently did not observe the tissue phases.

Let us drop one class lower to the reptiles. Here are found snakes parasitized with the *I. bigemina*-type in the form of *Isospora dirumpens* Hoare (1933) and *I. dirumpens* var. *americana* Roudabush (1937). Hoare noted the sporocysts, measuring 10.4 x 8.0μ - 11.2 x 9.6μ, in the feces of puff-adders (*Bitis arietans*) in captivity. The unruptured oocysts, most of them completely developed, were found in only one snake. They are surrounded by a very thin membrane when mature, and measure 16.0 - 16.8μ x 9.6μ. The oocysts can be noted in sections of the intestinal wall, both in the *lamina propria* and in the epithelium. Thus, the oocysts of this species are not confined to the *lamina propria. I. dirumpens* var. *americana* is found in the bullsnake (*Pituophis sayi sayi*). Its oocysts vary in length from 17.6-22.0μ x 10.1-14.5μ; mean size, 19.6 x 11.8μ. The spores measure 9.6-13.2μ x 8.8-11.0μ; mean size, 9.9 x 11.17μ. As in the puff-adder, fully developed bigeminal oocysts are found situated in the subepithelium and epithelium of the small intestine. *I. laverani* (Hagenmuller, 1898) of the snake *Coelopeltis* sp. has similar characteristics.

Do Amphibia, the next lower class of vertebrates, harbor this general type of coccidium. Here the situation isn't so clear, but I have been unable to find an account of an *Isospora* in these hosts which tallies with those mentioned previously in respect to all four of their peculiar features, although a number of species of the genus *Isospora* are represented in them. Perhaps the nearest is *I. hylae* Mesnil, 1907, a parasite of the digestive tract of the frog *Hyla arborea* of Europe. The developmental stages are said to occur so abundantly in the small intestine that the lumen is virtually obliterated. All stages of sporogony are represented among oocysts from the rectum. The developed forms are ellipsoidal and provided with a thin wall enclosing two ovoidal spores. Each spore contains four sporozoites and, on one side, a large residual body. The oocysts measure 30.0-35.0μ x 20.0-25.0μ, and the spores

23.0 x 17.0μ. There is no extraresidual body. Unfortunately, neither schizogony nor the site of development in the intestinal wall, i.e., whether epithelium or sub-epithelium, seems to have been elucidated. *Isospora lieberkühni* (Labbé, 1894) of the frog *Rana esculenta,* a very similar microorganism, develops in the epithelium and lumen of the uriniferous tubules of the kidneys. Fertilization and all succeeding stages of sporogony come to pass in the lumen only. The developed oocyst has a thin wall enclosing two ovoid or fusiform spores 25.0-30.0μ long, each containing four sporozoites and a large spherical residual body. The thin oocyst membrane becomes disrupted, liberating the spores. Thus, in this case also, the matured spores develop in the host at or near the site of their formation. In this species subepithelial development, of course, is lacking. Perhaps it was in the Amphibia that the *I. bigemina*-type had its incipiency!

What about *Isospora* in fishes? Evidently this is the end of the road because, although I have thoroughly surveyed the Eimeriidae of fishes, no authentic *Isosporae* have been described from these hosts or lower vertebrate classes. The occurrence of the genus in invertebrates (slugs) is a puzzling circumstance, unless it was by convergent evolution; or was it a product of the food chain?

Summary

Isospora bigemina is a coccidian parasite of dogs and cats, belonging to the mammalian order Carnivóra, that has four outstanding peculiarities that mark it unmistakably. It has perhaps an exact counterpart, *I. hominis,* parasitizing man, an animal belonging to the mammalian order Primates. An almost identical form, *I. lutreolinae,* parasitizes the "guaicuica," a lower mammal of the order Marsupialia, and *I. boughtoni,* a similar species, has been found in the Virginia opossum. In the class Aves occurs, *I. buteonis,* another of the *I. bigemina*-type, described by Henry (1932) from hawks, but which she and others have found to occur also in certain owls. Thus, the *I. bigemina*-type is represented in but two orders of birds—Falconiformes and Strigiformes. The type is well-represented in the class Reptilia by *I. dirumpens, I. dirumpens* var. *americana* and *I. liberkühni* of Serpentes. The exact counterpart of these *Isosporae* has not been found in the class Amphibia, but *I. hylae* of the intestine and *I. lieberkühni* of the kidney of frogs have certain features in common with them. Since *Isospora* does not parasitize the classes Osteichthyes, Elasmobranchii and Agnatha, so far as is known today, the host lineage of this distinc-

tive type of *Isospora* cannot be traced further back phylogenetically than the Amphibia.

The host affinities of the *Isospora bigemina*-type do not seem to fit the facts of phylogeny, except in a broad sense. Speculation about the food chain might prove more profitable! It will be noted that all of the hosts of this coccidian type are carnivorous in their feeding habits. The guaicuica and opossums are notoriously cannibalistic.

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